

CLAIMS

1. A magnetoresistive sensor comprising:

a first and a second layer of ferromagnetic material separated by a spacer layer of nonmagnetic material, the magnetization direction of said first layer of ferromagnetic material being substantially perpendicular to the magnetization direction of said second layer of ferromagnetic material at zero applied magnetic field;

a back layer of nonmagnetic electrically conductive material adjacent to and in contact with said first ferromagnetic layer, said back layer being coextensive with said first ferromagnetic layer covering substantially the entire first ferromagnetic layer; and

means for maintaining the magnetization in said second ferromagnetic layer in a desired direction.

2. A magnetoresistive sensor as in claim 1 wherein said means comprises an exchange bias layer of antiferromagnetic material adjacent to and in contact with said second ferromagnetic layer, said antiferromagnetic layer for providing a bias field in said second ferromagnetic layer for maintaining the magnetization in said second ferromagnetic layer in a desired direction.

3. A magnetoresistive sensor as in claim 2 wherein said antiferromagnetic layer is comprised of a material selected from the group consisting of iron-manganese and nickel-manganese.

4. A magnetoresistive sensor as in claim 3 wherein said antiferromagnetic layer is comprised of an alloy of iron-manganese.

5. A magnetoresistive sensor as in claim 2 wherein the thickness of said antiferromagnetic layer being within the range of about 50 angstroms to about 150 angstroms.

6. A magnetoresistive sensor as in claim 1 wherein the minimum thickness of said nonmagnetic back layer being about 4 angstroms.

~~7. A magnetoresistive sensor as in claim 6 wherein the maximum thickness of said nonmagnetic back layer being about three mean free path lengths for conduction electrons in said nonmagnetic back layer material.~~

8. A magnetoresistive sensor as in claim 6 wherein the thickness of said nonmagnetic back layer being within the range of about 4 angstroms to about 1000 angstroms.

9. A magnetoresistive sensor as in claim 6 wherein the thickness of said nonmagnetic back layer being within the range of about 4 angstroms to about 60 angstroms.

10. A magnetoresistive sensor as in claim 1 wherein the thickness of said first and said second ferromagnetic layers each being within the range of about 5 angstroms to about 150 angstroms.

11. A magnetoresistive sensor as in claim 10 wherein the thickness of said first ferromagnetic layer being within the range of about 5 angstroms to about 30 angstroms.

12. A magnetoresistive sensor as in claim 1 wherein said nonmagnetic spacer layer has a thickness less than the mean free path length of conduction electrons in said nonmagnetic spacer material.

13. A magnetoresistive sensor as in claim 12 wherein the thickness of said nonmagnetic spacer layer being within the range of about 10 angstroms to about 40 angstroms.

14. A magnetoresistive sensor as in claim 1 wherein said nonmagnetic spacer layer is comprised of a material selected from the group consisting of silver, gold, copper and alloys of silver, copper and gold.

15. A magnetoresistive sensor as in claim 14 wherein said nonmagnetic spacer layer comprises a thin film layer of copper.

16. A magnetoresistive sensor as in claim 1 wherein said nonmagnetic back layer is comprised of a material selected from the group consisting of silver, gold and copper.

17. A magnetoresistive sensor as in claim 16 wherein said nonmagnetic back layer comprises a thin film layer of copper.

18. A magnetoresistive sensor as in claim 1 wherein at least one of said first and second ferromagnetic layers comprise a multilayered structure.
19. A magnetoresistive sensor as in claim 18 wherein said multilayered structure comprises at least one layer of a first ferromagnetic material and at least one layer of a second ferromagnetic material, said layers being alternatively laminated.
20. A magnetoresistive sensor as in claim 18 wherein said first ferromagnetic layer comprises a thin layer of cobalt and a thin layer of nickel-iron, said thin layer of cobalt formed adjacent said nonmagnetic spacer layer.
21. A magnetoresistive sensor as in claim 18 wherein said first and second ferromagnetic layers each comprise a thin layer of cobalt and a thin layer of nickel-iron, said thin layer of cobalt formed adjacent said nonmagnetic spacer layer.
22. A magnetoresistive sensor as in claim 21 wherein the thickness of said thin layer of cobalt being within the range of about 0.5 angstroms to about 20 angstroms.
23. A magnetoresistive sensor as in claim 1 wherein both said nonmagnetic back layer and said nonmagnetic spacer layer comprise the same nonmagnetic material.
24. A magnetoresistive sensor as in claim 1 wherein both said nonmagnetic back layer and said nonmagnetic spacer layer comprise different nonmagnetic materials.
25. A magnetic storage system comprising:
 - a magnetic storage medium having a plurality of tracks for recording of data;
 - a magnetic transducer maintained in a closely spaced position relative to said magnetic storage medium during relative motion between said magnetic transducer and said magnetic storage medium, said magnetic transducer including a magnetoresistive sensor comprising:
 - a first and a second layer of ferromagnetic material separated by a spacer layer of nonmagnetic material, the magnetization direction of said first layer of ferromagnetic material being substantially perpendicular to the magnetization direction of said second layer of ferromagnetic material at zero applied magnetic field.

a back layer of nonmagnetic electrically conductive material adjacent to and in contact with said first ferromagnetic layer, said back layer being coextensive with said first ferromagnetic layer covering substantially the entire first ferromagnetic layer; and

bias means for maintaining the magnetization in said second ferromagnetic layer in a desired direction;

actuator means coupled to said magnetic transducer for moving said magnetic transducer to selected tracks on said magnetic storage medium; and

detection means coupled to said magnetoresistive sensor for detecting resistance changes in said magnetoresistive sensor in response to magnetic fields intercepted by said magnetoresistive sensor, said magnetic fields representative of data bits recorded in said magnetic storage medium.

26. A magnetic storage system as in claim 25 wherein said bias means comprises an exchange bias layer of antiferromagnetic material adjacent to and in contact with said second ferromagnetic layer, said antiferromagnetic layer for providing a bias field in said second ferromagnetic layer for maintaining the magnetization in said second ferromagnetic layer in a desired direction.

27. A magnetic storage system as in claim 26 wherein said antiferromagnetic layer is comprised of a material selected from the group consisting of iron-manganese and nickel-manganese.

28. A magnetic storage system as in claim 26 wherein said magnetoresistive sensor further comprises:

a capping layer deposited over said antiferromagnetic layer; and

electrical lead means deposited over said capping layer for coupling said magnetoresistive sensor to said detection means.

29. A magnetic storage system as in claim 28 wherein said capping layer comprises a material selected from the group consisting of tantalum and zirconium.

30. A magnetic storage system as in claim 26 wherein said nonmagnetic spacer layer is comprised of a material selected from the group consisting of silver, gold, copper and alloys of silver, copper and gold.

31. A magnetic storage system as in claim 30 wherein said nonmagnetic spacer layer comprises a thin film layer of copper.

32. A magnetic storage system as in claim 25 wherein said nonmagnetic back layer is comprised of a material selected from the group consisting of silver, gold and copper.

33. A magnetic storage system as in claim 32 wherein said nonmagnetic back layer comprises a thin film layer of copper.

34. A magnetoresistive sensor comprising:

a first and a second layer of ferromagnetic material separated by a spacer layer of a nonmagnetic conductive material, the direction of magnetization in said first and second layers of ferromagnetic material responsive to a magnetic field generated by a sense current in said magnetoresistive sensor being oriented at equal and opposite angles with respect to the sensor magnetic easy axis;

a first back layer of nonmagnetic electrically conductive material adjacent to and in contact with said first ferromagnetic layer, said first ferromagnetic layer disposed between said first back layer and said spacer layer, said first back layer being coextensive with said first ferromagnetic layer covering substantially the entire first ferromagnetic layer; and

a second back layer of nonmagnetic electrically conductive material adjacent to and in contact with said second ferromagnetic layer, said second ferromagnetic layer disposed between said second back layer and said spacer layer, said second back layer being coextensive with said second ferromagnetic layer covering substantially the entire second ferromagnetic layer.

35. A magnetoresistive sensor as in claim 34 wherein the minimum thickness of said first and said second nonmagnetic back layers each being about 4 angstroms.

36. A magnetoresistive sensor as in claim 35 wherein the maximum thickness of said first and said second nonmagnetic back layers each being about three mean free path lengths for conduction electrons in said nonmagnetic back layer material, respectively.

37. A magnetoresistive sensor as in claim 35 wherein the thickness of said first and said second nonmagnetic back layers each being within the range of about 4 angstroms to about 1000 angstroms.

38. A magnetoresistive sensor as in claim 35 wherein the thickness of said first and said second nonmagnetic back layers each being within the range of about 4 angstroms to about 60 angstroms.

39. A magnetoresistive sensor as in claim 34 wherein the thickness of said first and said second ferromagnetic layers each being within the range of about 5 angstroms to about 30 angstroms.

40. A magnetoresistive sensor as in claim 34 wherein said nonmagnetic spacer layer has a thickness less than the mean free path length of conduction electrons in said nonmagnetic spacer material.

41. A magnetoresistive sensor as in claim 40 wherein the thickness of said nonmagnetic spacer layer being within the range of about 10 angstroms to about 40 angstroms.

42. A magnetoresistive sensor as in claim 34 wherein said nonmagnetic spacer layer is comprised of a material selected from the group consisting of silver, gold, copper and alloys of silver, copper and gold.

43. A magnetoresistive sensor as in claim 34 wherein said first and second nonmagnetic back layers are comprised of a material selected from the group consisting of silver, gold and copper.

44. A magnetoresistive sensor as in claim 43 wherein said first and second nonmagnetic back layers each comprise a thin film layer of copper.

45. A magnetoresistive sensor comprising.

~~a first and a second layer of ferromagnetic material separated by a spacer layer of nonmagnetic material, the direction of magnetization of said first layer of ferromagnetic material being substantially perpendicular to the direction of magnetization of said second layer of ferromagnetic material at zero applied magnetic field; and~~

a back layer of nonmagnetic electrically conductive material adjacent to and in contact with said first layer of ferromagnetic material, said back layer being coextensive with said first ferromagnetic layer covering substantially the entire first ferromagnetic layer.

46. A magnetoresistive sensor as in claim 45, the minimum thickness of said nonmagnetic back layer being about 4 angstroms.

47. A magnetoresistive sensor as in claim 45, wherein said nonmagnetic back layer is comprised of a material selected from the group consisting of silver, gold and copper.

ABSTRACT

A MAGNETORESISTIVE SPIN VALVE SENSOR AND MAGNETIC
STORAGE SYSTEM INCORPORATING SUCH A SENSOR

A magnetoresistive read sensor based on the spin valve effect is described, in which a component of the read element resistance varies as the cosine of the angle between the magnetization directions in two adjacent magnetic layers. The sensor read element includes two adjacent ferromagnetic layers separated by a nonmagnetic metallic layer. A layer of nonmagnetic electrically conductive material is deposited adjacent to and in contact with at least one of the ferromagnetic layers (referred to as a filter layer) to form a back or conduction layer which provides a low resistance path for conduction electrons transmitted through the adjacent filter layer. The thickness of the filter layer is selected such that it effectively blocks conduction electrons having spins antiparallel to the direction of magnetization in the filter layer while allowing conduction electrons with parallel spins to be transmitted through the layer into the adjacent back layer. The magnetization of the filter layer is free to rotate in response to an applied magnetic field thereby effectively varying the electrically resistance to conduction electrons in the back/filter layer. The thickness of the back layer is selected to optimize the sensor parameters being measured and is in a range of about 4.0A to 1000A.